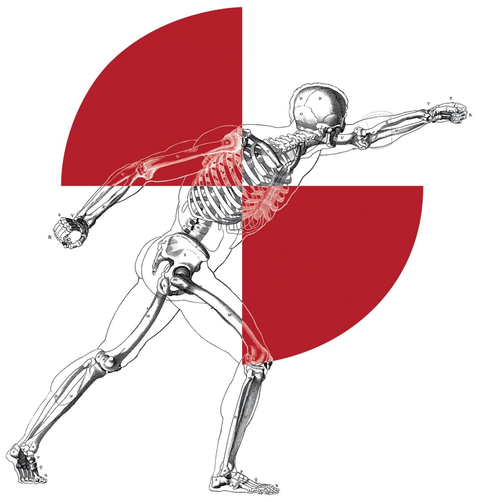

Analyzing the Influence of Trial Order on Seat Belt Fit for Pediatric Occupants in Reclined Vehicle Configurations

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INTRODUCTION

- Recent work has begun to investigate reclined child configurations during dynamic impacts, but the initial ATD positioning in these tests was likely not naturalistic [1].
- Examination of reclined static postures can inform initial child position in future sled testing and finite element simulations.
- Measuring child posture in recline conditions over multiple trials could potentially be biased due to a child's "slouching" behavior which may also influence belt fit [2].
- **The goal of this analysis was to evaluate the influence of condition order on child seat belt fit in reclined vehicle configurations.**

MATERIALS & METHODS

- Forty-three children between 4-12 years were recruited. Each child was evaluated in a mock-up vehicle seat under six conditions: with and without a backless booster in each of three recline angles (upright (25°), moderately reclined (45°), and reclined (60°)) (Figure 1).
- The order of the trials for each participant was randomized; however, all booster or vehicle trials were grouped together.
- Twenty-five children were evaluated on the booster first, and eighteen children were evaluated on the vehicle seat first.

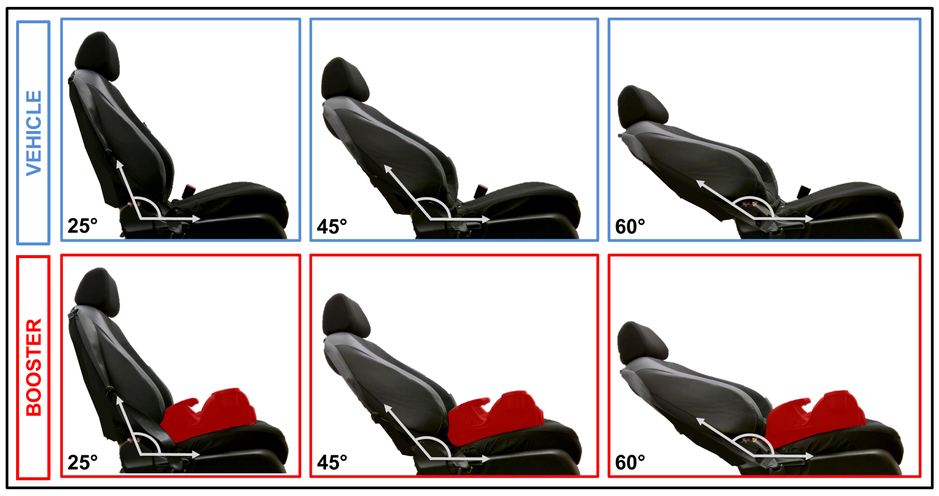

Figure 1: Recline and Seating Conditions

- The "detailed order" variable represents the sequence of each condition (1–6) corresponding to the order the participant completed the trials. The "simple order" (1 or 2) represents the overall order of seating conditions (booster or vehicle) for each participant, without considering recline angle (Figure 2).

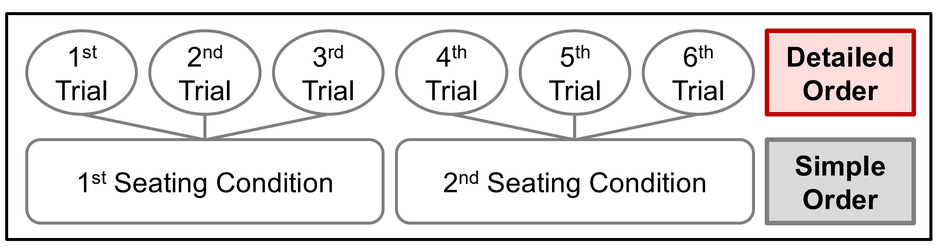

Figure 2: Order Methodology

MATERIALS & METHODS (continued)

- A 3D coordinate measurement device was then used to measure anatomic and seat belt landmarks (such as left and right anterior superior iliac spine (ASIS), sternal notch, etc.) according to the SAE J211 coordinate system [3].
- Seat belt fit metrics included the Y and Z positions of the shoulder belt with respect to (wrt) sternal notch and the X and Z positions of the lap belt wrt the ASIS (Figure 3).
- Variation in belt fit with seating configuration order and the order of the all trials was assessed using nonparametric Wilcoxon/Kruskal-Wallis tests (alpha=0.05).

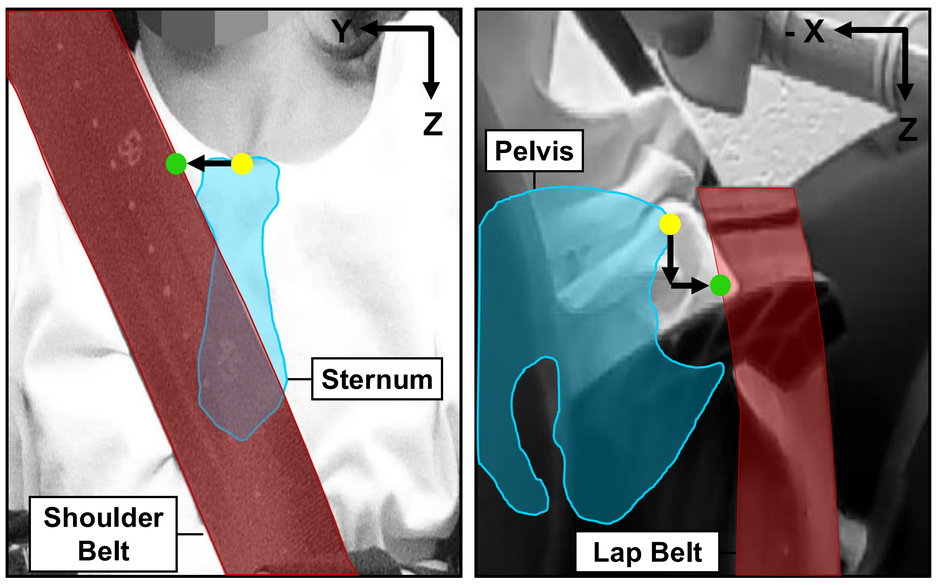

Figure 3: Seat Belt Fit Measurements

RESULTS

- Detailed or simple order were not significantly related to most belt fit variables with a few exceptions.
- The left lap belt wrt ASIS Z was statistically significant across simple and detailed orders on the booster. The right lap belt wrt ASIS Z in the vehicle condition across simple and detailed order (Table 1, Table 2).
- However, the difference in means of the statistically significant variables was relatively small (< 8 mm).

Table 1: Simple Order Results

Variable	Direction	Condition	p-value	1st Seating Condition (mm)	2nd Seating Condition (mm)
Shoulder Belt wrt Sternal Notch	Y	Booster	0.4102	47 ± 19	44 ± 21
		Vehicle	**0.0297**	-1 ± 18	6 ± 19
	Z	Booster	0.7185	-11 ± 9	-10 ± 8
		Vehicle	0.4102	-16 ± 8	-18 ± 8
Lap Belt wrt Left ASIS	X	Booster	0.4843	49 ± 21	46 ± 18
		Vehicle	0.2058	-10 ± 13	-14 ± 17
	Z	**Booster**	**0.0004**	-8 ± 8	-13 ± 7
		Vehicle	0.1555	-11 ± 10	-8 ± 6
Lap Belt wrt Right ASIS	X	Booster	0.7221	58 ± 21	55 ± 21
		Vehicle	0.1260	-2 ± 14	-7 ± 17
	Z	**Booster**	**0.0167**	-8 ± 9	-12 ± 8
		Vehicle	**0.0016**	-6 ± 7	-3 ± 5

DISCUSSION & CONCLUSIONS

- Minor changes in child posture and belt fit throughout all the trials were observed for some variables; however, differences were generally small in magnitude. These results do not provide strong evidence to consider including condition order as an additional independent variable in future comparisons of belt fit outcomes between reclined and seating conditions.
- In addition, other aspects, such as variation in child behavior in posture in the reclined configurations over time, must also be considered.

Table 2: Detailed Order Results

Variable	Direction	Condition	p-value	1st Trial (mm)	2nd Trial (mm)	3rd Trial (mm)	4th Trial (mm)	5th Trial (mm)	6th Trial (mm)
Shoulder Belt wrt Sternal Notch	Y	Booster	0.4420	45 ± 17	49 ± 21	48 ± 18	45 ± 26	37 ± 15	49 ± 21
		Vehicle	0.1958	0 ± 17	-1 ± 21	-2 ± 18	7 ± 18	9 ± 20	2 ± 20
	Z	Booster	0.7208	-12 ± 9	-12 ± 7	-10 ± 10	-9 ± 7	-10 ± 9	-12 ± 8
		Vehicle	0.6140	-14 ± 6	-18 ± 9	-17 ± 8	-18 ± 8	-18 ± 6	-18 ± 9
Lap Belt wrt Left ASIS	X	Booster	0.6183	53 ± 22	50 ± 19	44 ± 21	45 ± 16	44 ± 15	48 ± 23
		Vehicle	0.2730	-8 ± 13	-9 ± 9	-13 ± 15	-11 ± 15	-12 ± 16	-19 ± 18
	Z	**Booster**	**0.0035**	-8 ± 9	-9 ± 6	-6 ± 8	-13 ± 6	-11 ± 7	-13 ± 8
		Vehicle	0.6241	-11 ± 10	-12 ± 8	-12 ± 11	-8 ± 6	-8 ± 5	-9 ± 6
Lap Belt wrt Right ASIS	X	Booster	0.3982	62 ± 20	59 ± 22	51 ± 20	57 ± 21	51 ± 16	58 ± 25
		Vehicle	0.5510	-1 ± 15	-1 ± 10	-4 ± 15	-5 ± 16	-7 ± 18	-10 ± 18
	Z	Booster	0.0625	-9 ± 8	-9 ± 9	-5 ± 8	-13 ± 8	-10 ± 7	-12 ± 8
		Vehicle	**0.0267**	-5 ± 5	-7 ± 5	-7 ± 10	-3 ± 6	-3 ± 3	-4 ± 6

REFERENCES CITED

[1] Graci, V., Humm, J., & Hauschild, H. (2024). The effect of reclined seat-back angles on the LODC with and without a belt-positioning booster during far-side lateral-oblique impacts. Traffic Injury Prevention, 25(sup1), S208–S218. https://doi.org/10.1080/15389588.2024.2358993

[2] Connell R., Baker G., Mansfield J. Changes in Naturalistic Postures Observes in Belt Positioning Booster Seats Over Time. *Proceedings of the 2024 IRCOBI Conference*, 2024, Stockholm, Sweden. IRC-24-112

[3] SAE International (March 2014). Instrumentation for Impact Test – Part 1 – Electronic Instrumentation, Section 7.1

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